CMSC 330: Organization of Programming Languages

Introduction to Ruby
Ruby

- An object-oriented, imperative, dynamically typed (scripting) language
  - Created in 1993 by Yukihiro Matsumoto (Matz)
  - “Ruby is designed to make programmers happy”
  - Core of Ruby on Rails web programming framework (a key to its popularity)
  - Similar in flavor to many other scripting languages
    - Much cleaner than perl
  - Full object-orientation (even primitives are objects!)
Books on Ruby

- Earlier version of Thomas book available on web
  - See course web page
Applications of Scripting Languages

- Scripting languages have many uses
  - Automating system administration
  - Automating user tasks
  - Quick-and-dirty development

- Motivating application

Text processing
Output from Command-Line Tool

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<tr>
<td>Median House Value</td>
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</tr>
</tbody>
</table>

---

CMSC 330 - Spring 2018
A Simple Example

Let’s start with a simple Ruby program

ruby1.rb:

```ruby
# This is a ruby program
x = 37
y = x + 5
print(y)
print("\n")
```

```
ruby -w ruby1.rb
42
%
```
Language Basics

comments begin with #, go to end of line

variables need not be declared

no special main() function or method

line break separates expressions (can also use “;” to be safe)

```ruby
# This is a ruby program
x = 37
y = x + 5
print(y)
print("\n")
```
Run Ruby, Run

There are two basic ways to run a Ruby program

• **ruby -w filename** – execute script in `filename`
  - tip: the `-w` will cause Ruby to print a bit more if something bad happens
  - Ruby filenames should end with `.rb` extension

• **irb** – launch interactive Ruby shell
  - Can type in Ruby programs one line at a time, and watch as each line is executed
    ```ruby
    irb(main):001:0> 3+4
    => 7
    ```
  - Can load Ruby programs via `load` command
    - Form: `load string`
    - String must be name of file containing Ruby program
    - E.g.: `load 'foo.rb'`

- Ruby is installed on Grace cluster
Run Ruby, Run (cont.)

- `fxri` – launch standalone interactive Ruby shell

This is `fxri`, a graphical interface to the Ruby documentation. Fxri comes with a search engine with quite a few features. Here are several examples:

- `'Array'`: Lists all classes with the name `Array`. Note that uppercase words are treated case sensitive, lowercase words insensitive.

- `'array sort'`: Everything that contains both `array` and `sort` (case insensitive).

- `'array -Fox'`: Everything that contains the name `array` (case insensitive), but not `Fox` (case sensitive).

After searching just press `down` to browse the search results. Press `Tab` to move back into the search field.

If you have any questions, suggestions, problems, please contact the current maintainer with `markus.prinz@qsig.org`.

Original author: Martin Ankerl (`martin.ankerl@gmail.com`).

```
irb(main):001:0> 
```
Suppose you want to run a Ruby script as if it were an executable (e.g. “double-click”, or as a command)

- **Windows**
  - Must associate .rb file extension with ruby command
  - If you installed Ruby using the Windows installer, this was done automatically
  - The Ruby web site has information on how to make this association
Run Ruby, Run (cont.)

- Suppose you want to run a Ruby script as if it were an executable (cont.)
  - *nix (Linux / Unix / etc.)

```ruby
#!/usr/local/bin/ruby -w
print("Hello, world!\n")
```

- The first line ("shebang") tells the system where to find the program to interpret this text file
- Must `chmod u+x filename` first, or `chmod a+x filename` so everyone has exec permission
- Warning: Not very portable: Depends on location of Ruby interpreter
  - `/usr/local/bin/ruby` vs. `/usr/bin/ruby` vs. `/opt/local/bin/ruby` etc.
Creating Ruby Programs

- As with most programming languages, Ruby programs are text files.
  - Note: there are actually different versions of “plain text”! E.g. ASCII, Unicode, Utf-8, etc.
  - You won’t need to worry about this in this course.

- To create a Ruby program, you can use your favorite text editor, e.g.
  - notepad++ (free, much better than notepad)
  - emacs (free, infinitely configurable)
  - vim
  - Eclipse (see web page for plugin instructions)
  - Many others
Some Ruby Language Features

- Implicit declarations
  - Java, C have explicit declarations

- Dynamic typing
  - Java, C have (mostly) static typing

- Everything is an object
  - No distinction between objects and primitive data
  - Even “null” is an object (called \textit{nil} in Ruby), as are classes

- No outside access to private object state
  - \textit{Must} use getters, setters

- No method overloading

- Class-based and Mixin inheritance
Implicit vs. Explicit Declarations

- In Ruby, variables are implicitly declared
  - First use of a variable declares it and determines type
    \[ x = 37; \] // no declaration needed – created when assigned to
    \[ y = x + 5 \]
    - \( x, y \) now exist, are integers

- Java and C/C++ use explicit variable declarations
  - Variables are named and typed before they are used
    \[ \text{int } x, y; \] // declaration
    \[ x = 37; \] // use
    \[ y = x + 5; \] // use
Implicit vs. Explicit Declarations

- Explicit declarations identify allowed names
  - Variables must be declared before used

```c
void foo(int y) {
  int x;
  x = y + 1;
  return x + y;
}
```

C, Java, C++, etc.
Implicit vs. Explicit Declarations

- Allowed names also declared implicitly
  - Variables do not need to be declared
    - Implicit declaration when first assigned to

Ruby
```ruby
def foo(y)
    x = y + 1;
    return x + y;
end
```

Declared implicitly, when assigned

Use

Also: Perl, Python
## Tradeoffs?

<table>
<thead>
<tr>
<th>Explicit Declarations</th>
<th>Implicit Declarations</th>
</tr>
</thead>
<tbody>
<tr>
<td>More text to type</td>
<td>Less text to type</td>
</tr>
<tr>
<td>Helps prevent typos</td>
<td>Easy to mistype variable name</td>
</tr>
</tbody>
</table>

```python
var = 37
If (rare-condition)
y = vsr + 5
```

**Typo!**

Only caught when this line is actually run. Bug could be latent for quite a while.
Static Type Checking (Static Typing)

Before program is run
- Types of all expressions are determined
- Disallowed operations cause compile-time error
  - Cannot run the program

Static types are often explicit (aka manifest)
- Specified in text (at variable declaration)
  - C, C++, Java, C#
- But may also be inferred – compiler determines type based on usage
  - OCaml, C# and Go (limited)
Dynamic Type Checking

- **During** program execution
  - Can determine type from run-time value
  - Type is checked before use
  - Disallowed operations cause run-time exception
    - Type errors may be latent in code for a long time

- Dynamic types are *not manifest*
  - Variables are just introduced/used without types
  - Examples
    - Ruby, Python, Javascript, Lisp
Static and Dynamic Typing

- **Ruby** is dynamically typed, **C** is statically typed

```ruby
# Ruby
x = 3
x = "foo"  # gives x a  # new type
    # NoMethodError
x.foo     # at runtime
```

```c
/* C */
int x;
  x = 3;
  x = "foo";  /* not allowed */
  /* program doesn’t compile */
```

- **Notes**
  - Can always run the Ruby program; may fail when run
  - **C** variables declared, with types
    - Ruby variables declared *implicitly*
    - Implicit declarations most natural with dynamic typing
Tradeoffs?

- **Static type checking**
  - More work for programmer (at first)
    - Catches more (and subtle) errors at compile time
  - Precludes some correct programs
    - May require a contorted rewrite
  - More efficient code (fewer run-time checks)

- **Dynamic type checking**
  - Less work for programmer (at first)
    - Delays some errors to run time
  - Allows more programs
    - Including ones that will fail
  - Less efficient code (more run-time checks)
Java: *Mostly* Static Typing

- In Java, types are mostly checked statically
  
  ```java
  Object x = new Object();
  x.println("hello");  // No such method error at compile time
  ```

- But sometimes checks occur at run-time
  
  ```java
  Object o = new Object();
  String s = (String) o;  // No compiler warning, fails at run time
  // (Some Java compilers may be smart enough to warn about above cast)
  ```
Quiz 1: Get out your clickers!

- **True or false**: This program has a type error

```ruby
# Ruby
x = 3
y = "foo"
x = y
```

A. True  
B. False
Quiz 1: Get out your clickers!

- **True or false**: This program has a type error

```ruby
# Ruby
x = 3
y = "foo"
x = y
```

- **True or false**: This program has a type error

```c
/* C */
void foo() {
    int x = 3;
    char *y = "foo";
    x = y;
}
```
Quiz 1: Get out your clickers!

- **True or false**: This program has a type error

```ruby
# Ruby
x = 3
y = "foo"
x = y
```

- **True or false**: This program has a type error

```c
/* C */
void foo() {
    int x = 3;
    char *y = "foo";
x = y;
}
```

A. True
B. False
Control Statements in Ruby

- A control statement is one that affects which instruction is executed next
  - While loops
  - Conditionals

```ruby
i = 0
while i < n
  i = i + 1
end
```

```ruby
if grade >= 90 then
  puts "You got an A"
elsif grade >= 80 then
  puts "You got a B"
elsif grade >= 70 then
  puts "You got a C"
else
  puts "You’re not doing so well"
end
```
Conditionals and Loops Must End!

- All Ruby conditional and looping statements must be terminated with the end keyword.

Examples

- if grade >= 90 then
  puts "You got an A"
end

- if grade >= 90 then
  puts "You got an A"
else
  puts "No A, sorry"
end

- i = 0
  while i < n
    i = i + 1
  end
What is True?

- The **guard** of a conditional is the expression that determines which branch is taken

```plaintext
if grade >= 90 then
...
```

Guard

- The **true** branch is taken if the guard evaluates to anything except
  - `false`
  - `nil`

- Warning to C programmers: **0 is not false!**
Yet More Control Statements in Ruby

- `unless cond then stmt-f else stmt-t end`
  - Same as “if not cond then stmt-t else stmt-f end”

```
unless grade < 90 then
  puts "You got an A"
else unless grade < 80 then
  puts "You got a B"
end
```

- `until cond body end`
  - Same as “while not cond body end”

```
until i >= n
  puts message
  i = i + 1
end
```
Using If and Unless as Modifiers

- Can write if and unless after an expression
  - puts "You got an A" if grade >= 90
  - puts "You got an A" unless grade < 90

- Why so many control statements?
  - Is this a good idea? Why or why not?
    - **Good**: can make program more readable, expressing programs more directly. In natural language, many ways to say the same thing, which supports brevity and adds style.
    - **Bad**: many ways to do the same thing may lead to confusion and hurt maintainability (if future programmers don’t understand all styles)
Quiz 2: What is the output?

```ruby
x = 0
if x then
  puts "true"
elsif x == 0 then
  puts "== 0"
else
  puts "false"
end
```

A. “true”
B. “== 0”
C. “false”
D. Nothing – there’s an error
Quiz 2: What is the output?

```
x = 0
if x then
  puts "true"
elsif x == 0 then
  puts "== 0"
else
  puts "false"
end
```

A. “true”
B. “== 0”
C. “false”
D. Nothing – there’s an error

\(x\) is neither false nor nil so the first guard is satisfied
Other Useful Control Statements

```ruby
for elt in [1, “math”, 3.4]
  puts elt.to_s
end

for i in (1..3)
  puts i
end

(1..3).each { |elt|
  puts elt
}

IO.foreach(filename)
  { |x|
    puts x
  }

case x
  when 1, 3..5
    next
  when 2, 6..8
    break
end

while i>n
  break
  next
  puts message
  redo
end
```

*generates a string; cf. to_i*

do not need break

code block (details later)
Methods are declared with `def...end`.

List parameters at definition.

May omit parens on call.

Invoke method.

Like print, but adds newline.

Methods should begin with lowercase letter and be defined before they are called.

Variable names that begin with uppercase letter are *constants* (only assigned once).
Terminology

- **Formal parameters**
  - Variable parameters used in the method
  - `def sayN(message, n)` in our example

- **Actual arguments**
  - Values passed in to the method at a call
  - `x = sayN("hello", 3)` in our example

- **Top-level methods are “global”**
  - Not part of a class. `sayN` is a top-level method.
Method Return Values

- Value of the `return` is the value of the last executed statement in the method
  - These are the same:

```ruby
def add_three(x)
  return x+3
end
```

- Methods can return multiple results (as an Array)

```ruby
def dup(x)
  return x,x
end
```
Everything is an Object

- **All** values are (references to) objects
  - Java/C/C++ distinguish *primitives* from *objects*
- Objects communicate via **method calls**
- Each object has its own (private) **state**
- Every object is an instance of a **class**
  - An object’s class determines its behavior:
  - The class contains method and field definitions
    - Both instance fields and per-class (“static”) fields
Everything is an Object

Examples

• (-4).abs  No-argument instance method of Fixnum
  - integers are instances of class Fixnum
• 3 + 4
  - infix notation for “invoke the + method of 3 on argument 4”
• "programming".length
  - strings are instances of String
• String.new
  - classes are objects with a new method
• 4.13.class
  - use the class method to get the class for an object
  - floating point numbers are instances of Float
Classes

- Class names begin with an uppercase letter
- The `new` method creates an object
  - `s = String.new` creates a new `String` and makes `s` refer to it
- Every class inherits from `Object`
Objects and Classes

- Objects are data
- Classes are types (the kind of data which things are)
- Classes are also objects

<table>
<thead>
<tr>
<th>Object</th>
<th>Class (aka type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Fixnum</td>
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<tr>
<td>-3.30</td>
<td>Float</td>
</tr>
<tr>
<td>&quot;CMSC 330&quot;</td>
<td>String</td>
</tr>
<tr>
<td>String.new</td>
<td>String</td>
</tr>
<tr>
<td>[‘a’, ‘b’, ‘c’]</td>
<td>Array</td>
</tr>
<tr>
<td>Integer</td>
<td>Class</td>
</tr>
</tbody>
</table>

- Integer, Float, and String are objects of type **Class**
  - So is Class itself!
Two Cool Things to Do with Classes

- Since classes are objects, you can manipulate them however you like
  - Here, the type of \( y \) depends on \( p \)
    - Either a String or a Time object

- You can get names of all the methods of a class
  - \texttt{Object.methods}
    - \( => \) ["send", "name", "class_eval", "object_id", "new", "autoload?", "singleton\_methods", ... ]

```ruby
if p then
  x = String
else
  x = Time
End
y = x.new
```
The nil Object

- Ruby uses a special object **nil**
  - All uninitialized fields set to **nil** (@ prefix used for fields)
    
    ```ruby
    irb(main):004:0> @x
    => nil
    ```
  - Like NULL or 0 in C/C++ and null in Java

- **nil** is an object of class **NilClass**
  - It’s a *singleton object* – there is only one instance of it
    - NilClass does not have a **new** method
  - **nil** has methods like **to_s**, but not other methods
    
    ```ruby
    irb(main):006:0> nil + 2
    NoMethodError: undefined method `+' for nil:NilClass
    ```
Quiz 3

What is the type of variable $x$ at the end of the following program?

```ruby
p = nil
x = 3
if p then
  x = nil
else
  x = "hello"
end
```

A. String  
B. Integer  
C. NilClass  
D. *Nothing* – there’s a type error
Quiz 3

What is the type of variable \( x \) at the end of the following program?

\[
\begin{align*}
p &= \text{nil} \\
x &= 3 \\
\text{if } p \text{ then} \\
\quad x &= \text{nil} \\
\text{else} \\
\quad x &= \text{“hello”} \\
\text{end}
\end{align*}
\]

A. String
B. Integer
C. NilClass
D. Nothing – there’s a type error
Creating Strings in Ruby

- Substitution in double-quoted strings with #{ }:
  - course = "330"; msg = "Welcome to #{course}"
  - "It is now #{Time.new}"  
  - The contents of #{ } may be an arbitrary expression
  - Can also use single-quote as delimiter
    - No expression substitution, fewer escaping characters

- Here-documents:
  ```ruby
  s = <<END
     This is a text message on multiple lines
     and typing \n is annoying
  END
  ```

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Creating Strings in Ruby (cont.)

- Ruby has `printf` and `sprintf`
  - `printf("Hello, %s\n", name);`
  - `sprintf("%d: %s", count, Time.now)`
    - Returns a String

- `to_s` returns a **String** representation of an object
  - Can be invoked implicitly – write `puts(p)` instead of `puts(p.to_s)`
    - Like Java’s `toString()`

- `inspect` converts **any** object to a string
  ```ruby
  irb(main):033:0> p.inspect
  => "#<Point:0x54574 @y=4, @x=7>"
  ```
Standard Library: String

- The **String** class has many useful methods
  - `s.length`  # length of string
  - `s1 == s2`  # structural equality (string contents)
  - `s = "A line\n"; s.chomp`  # returns "A line"
    - Return new string with `s`'s contents except newline at end of line removed
  - `s = "A line\n"; s.chomp!`
    - Destructively removes newline from `s`
    - *Convention*: methods ending in `!` modify the object
    - *Another convention*: methods ending in `?` observe the object
Symbols

- Ruby *symbols* begin with a colon
  - :foo, :baz_42, :"Any string at all"

- Symbols are “interned” *Strings*
  - The same symbol is at the same physical address
  - Can be compared with physical equality

```
"foo" == "foo"     # true
"foo".equal? "foo"  # false
:foo == :foo       # true
:foo.equal :foo    # true
```

- Are symbols worth it? Probably not…
Method naming style

Names of methods that return `true` or `false` should end in `?`

Names of methods that modify an object’s state should end in `!`

Example: suppose `x = [3,1,2]` (this is an array)

- `x.member? 3` returns true since 3 is in the array `x`
- `x.sort` returns a new array that is sorted
- `x.sort!` modifies `x` in place
# Defining Your Own Classes

```ruby
class Point
  def initialize(x, y)
    @x = x
    @y = y
  end

  def add_x(x)
    @x += x
  end

  def to_s
    return "(" + @x.to_s + "," + @y.to_s + ")"
  end
end

p = Point.new(3, 4)
p.add_x(4)
puts(p.to_s)
```

- **class name is uppercase**: `Point`
- **constructor definition**: `initialize(x, y)`
- **instance variables prefixed with “@”**: `@x`, `@y`
- **method with no arguments**: `add_x(x)`
- **instantiation**: `Point.new(3, 4)`
- **invoking no-arg method**: `puts(p.to_s)`
No Outside Access To Internal State

- Instance variables (with @) can be directly accessed only by instance methods
- Outside class, they require **accessors**:

  ```ruby
  A typical getter
  def x
    @x
  end

  A typical setter
  def x= (value)
    @x = value
  end
  ```

- Very common, so Ruby provides a shortcut

  ```ruby
  class ClassWithXandY
    attr_accessor :x, :y
  end
  ```

  Says to generate the `x=`, `x`, `y=`, and `y` methods
No Method Overloading in Ruby

- Thus there can only be one `initialize` method
  - A typical Java class might have two or more constructors

- No overloading of methods in general
  - You can code up your own overloading by using a variable number of arguments, and checking at run-time the number/types of arguments

- Ruby does issue an exception or warning if a class defines more than one `initialize` method
  - But last `initialize` method defined is the valid one
Quiz 4: What is the output?

class Dog
    def smell(thing)
        "I smelled #{thing}"
    end
    def smell(thing,dur)
        "I smelled #{thing} for #{dur} seconds"
    end
end

fido = Dog.new
puts fido.smell("Alice")

A. I smelled Alice for nil seconds
B. Error
C. I smelled #{thing}
D. I smelled Alice
class Dog
  def smell(thing)
    "I smelled #{thing}"  
  end
  def smell(thing,dur)
    "I smelled #{thing} for #{dur} seconds"
  end
end
fido = Dog.new
puts fido.smell("Alice")

A. I smelled Alice for nil seconds
B. Error
C. I smelled #{thing}
D. I smelled Alice
Quiz 5: What is the output?

class Dog
  def smell(thing)
    "I smelled #{thing}"
  end
  def smell(thing,dur)
    "I smelled #{thing} for #{dur} seconds"
  end
end
fido = Dog.new
puts fido.smell("Alice",3)

A. I smelled Alice for 3 seconds
B. Error
C. I smelled #{thing} for #{dur} seconds
D. I smelled Alice for 3 seconds
Quiz 5: What is the output?

```ruby
class Dog
  def smell(thing)
    "I smelled #{thing}"
  end
  def smell(thing,dur)
    "I smelled #{thing} for #{dur} seconds"
  end
end
fido = Dog.new
puts fido.smell("Alice",3)
```

A. I smelled Alice for 3 seconds
B. Error
C. I smelled #{thing} for #{dur} seconds
D. I smelled Alice for 3 seconds
Inheritance

Recall that every class inherits from \texttt{Object}

```ruby
class A  #< Object
  def add(x)
    return x + 1
  end
end

class B < A
  def add(y)
    return (super(y) + 1)
  end
end

b = B.new
puts(b.add(3))
```

- `b.is_a? A` → true
- `b.instance_of? A` → false
super( ) in Ruby

- Within the body of a method
  - Call to super( ) acts just like a call to that original method
  - Except that search for method body starts in the superclass of the object that was found to contain the original method
class Gunslinger
  def initialize(name)
    @name = name
  end
  def full_name
    "#{@name}"
  end
end

class Outlaw < Gunslinger
  def full_name
    "Dirty, no good #{super}"
  end
end

d = Outlaw.new("Billy the Kid")
puts d.full_name

Quiz 6: What is the output?
A. Dirty, no good
B. Dirty, no good Billy the kid
C. Billy the Kid
D. Error
Quiz 6: What is the output?

class Gunslinger
  def initialize(name)
    @name = name
  end
  def full_name
    "#{@name}"
  end
end

class Outlaw < Gunslinger
  def full_name
    "Dirty, no good #{super}"
  end
end
d = Outlaw.new("Billy the Kid")
puts d.full_name

A. Dirty, no good
B. Dirty, no good Billy the kid
C. Billy the Kid
D. Error
Mixins

- Another form of code reuse is “mix-in” inclusion
  - `include A` “inlines” A’s methods at that point
    - Referred-to variables/methods captured from context
    - In effect: it adds those methods to the current class

```ruby
class OneDPoint
  attr_accessor :x
  include Comparable
  def <=>(other) # used by Comparable
    if @x < other.x then return -1
    elsif @x > other.x then return 1
    else return 0
    end
  end
end
```

```ruby
p = OneDPoint.new
p.x = 1
q = OneDPoint.new
q.x = 2
x < y # true
puts [y,x].sort
# prints x, then y
```
Global Variables in Ruby

- Ruby has two kinds of global variables
  - Class variables beginning with @@ (static in Java)
  - Global variables across classes beginning with $

```ruby
class Global
  @@x = 0

  def Global.inc
    @@x = @@x + 1; $x = $x + 1
  end

  def Global.get
    return @@x
  end
end
```

$x = 0
Global.inc
$x = $x + 1
Global.inc
puts(Global.get)
puts($x)

define a class ("singleton") method
Quiz 7: What is the output?

class Animal
  def initialize(h, w)
    @@h = h
    @w = w
  end
  def measure()
    return @@h + @w
  end
end

giraffe = Animal.new(1,2)
elephant = Animal.new(3,4)
puts giraffe.measure()
Quiz 7: What is the output?

class Animal
  def initialize(h, w)
    @@h = h
    @w = w
  end
  def measure()
    return @@h + @w
  end
End

giraffe = Animal.new(1,2)
elephant = Animal.new(3,4)
puts giraffe.measure()
Special Global Variables

- Ruby has a special set of global variables that are implicitly set by methods
- The most insidious one: \$_
  - Last line of input read by gets or readline
- Example program

```
gets    # implicitly reads input line into \$_
print   # implicitly prints out \$_
```

- Using \$_ leads to shorter programs
  - And confusion
  - We suggest you avoid using it
What is a Program?

- In C/C++, a program is...
  - A collection of declarations and definitions
  - With a distinguished function definition
    - `int main(int argc, char *argv[]) { ... }`
  - When you run a C/C++ program, it’s like the OS calls `main(...)`

- In Java, a program is...
  - A collection of class definitions
  - With some class (say, `MyClass`) containing a method
    - `public static void main(String[] args)`
  - When you run `java MyClass`, the main method of class `MyClass` is invoked
A Ruby Program is...

- The class `Object`
  - When the class is loaded, any expressions not in method bodies are executed

```ruby
def sayN(message, n)
i = 0
while i < n
  puts message
  i = i + 1
end
return i
end
```

```
x = sayN("hello", 3)
puts(x)
```

defines a method of Object (i.e., top-level methods belong to Object)

invokes `self.sayN`

invokes `self.puts` (part of `Object`)
Summary

- Scripting languages
- Ruby language
  - Implicit variable declarations
  - Dynamic typing
  - Many control statements
  - Classes & objects
  - Strings